BELLCOMM, INC.

SUBJECT: Methods for Docking the LMSS Payload Module to the Multiple Docking Adapter
Case 600-3

DATE: January 9, 1967

FROM: W. W. Hough

ABSTRACT

This memorandum outlines six possible methods for docking the LMSS Payload Module (PM) to the multiple docking adapter (MDA) of the Orbital Assembly as part of the mid-1968 Apollo Applications missions. In the present design, which has evolved around Apollo Mission 504-C, the PM can be docked to only a CSM. Each of the six docking methods requires unique configuration changes in the PM design. Extent, and consequently cost of the modifications can be diminished at the expense of operational complexity and/or sacrifice of objectives.

In five of the six cases the CSM actively performs the docking maneuver, and therefore two docking ports are required on the PM. A forward port already exists. In two cases, the additional port is permanently mounted directly opposite the existing port, and this requires relocation of the PM battery compartment. In a third method, the aft port is mounted by EVA. An 11° offset port can be installed without major changes in the PM, but retention of the rack with the PM is required. If it is feasible to side-dock the PM to the MDA, neither battery compartment relocation nor rack retention is necessary, but CSM control logic changes are required. The method that does not require addition of a docking port is to snare the PM on two booms that have been automatically extended from the MDA. After MDA activation, the crew reels the PM into the docked position.

Three of the methods require that the CSM transpose around the PM so that when the CSM docks it to the MDA, the LMSS film canisters are accessible from within the internal volume of the MDA. During this transposition maneuver, the PM must be stabilized. Addition of a PM attitude control system or temporary attachment of the PM to the stabilized Orbital Assembly will meet this requirement.

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(NASA-CR-153723) METHODS FOR DOCKING THE LMSS PAYLOAD MODULE TO THE MULTIPLE DOCKING ADAPTER (Bellcomm, Inc.) 13 p

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MEMORANDUM FOR FILE

1.0 INTRODUCTION

This memorandum outlines six possible methods for docking the LMSS Payload Module (PM) to the multiple docking adapter (MDA) of the Orbital Assembly. As presently planned, the LMSS earth-orbital checkout mission will be performed with Uprated Saturn I AS-207 (AAP-1), and after approximately five days at 105 to 125 NM, the CSM will transfer to 270 NM and rendezvous with the Orbital Workshop that has been launched unmanned to that altitude with AS-209 (AAP-2). If the PM is taken along and docked to the MDA for later reuse as part of the Orbital Assembly/LM-ATM missions, AS-210 and 211 (AAP-3 and -4) modifications to the Payload Module are required. In the present design, which has evolved around Apollo Mission 504-C, the LMSS is not capable of reuse, and the PM can be docked to only a CSM.

Each of the six possible docking methods described requires unique configuration changes in the Payload Module design. Extent, and consequently cost, of the modifications can be diminished at the expense of operational complexity and/or sacrifice of some reuse objectives. In five of the six cases, the CSM actively performs the docking maneuver. In these cases, two docking ports are required on the PM. One is the existing port, and since it is forward in the launch configuration, it will be called the forward port in this memorandum. In two cases, the additional port is permanently mounted on the opposite end of the PM which requires either relocation of the aft battery compartment or translation of the PM launch position forward so the additional port may be attached aft of the battery compartment. In the present design, the clearance between the battery compartment and the top of the S-IVB hydrogen tank is already at the minimum of eight inches. If either of these modifications are too extensive, there are two other methods of installing the aft docking collar. One is to install it by EVA after rendezvous with the Workshop is accomplished; the other is to permanently mount it offset from the axial centerline such that it clears the battery compartment. This latter method is the only one that requires retention of the launch support rack with the PM. The fifth method is to dock the side

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of the PM to the MDA, which, if feasible at all, requires changes to the CSM control logic. The sixth method is to snare the PM after Workshop rendezvous on two booms that have been automatically extended from the MDA. After MDA activation,the crew reels the PM into the docked position.

2.0 COMMON MODIFICATIONS AND OPERATIONS

Table I lists, for the six methods, PM and rack modifications and in-flight operations required. Several modifications and operations are common to two or more of the docking methods, and will be described prior to the detailed presentation of the methods.

2.1 Addition of Permanent Aft Docking Collar

As mentioned in the introduction, the present clearance between the PM battery compartment and the top of the S-IVB hydrogen tank is eight inches, the specified minimum. Permanent mounting of the extra docking collar and drogue on the aft end of the PM requires that the battery compartment be moved. There are two feasible ways of doing this:

2.1.1 It may be relocated forward of the PM-rack separation joint. This can be done by repackaging it around the circumference of the PM, or mounting it as a unit to the side of the PM opposite the IR baffle.

2.1.2 It may be relocated by translating the launch position of the entire PM forward relative to the SLA. However to obtain the proper clearance between the aft docking collar and the tank, the forward end of the PM must be inside the CSM SPS nozzle during launch. As a consequence, pre-separation engine gimbal checkout is limited. To maintain on-pad access to the battery compartment, the launch support rack should be moved forward by the same amount rather than translating the PM within the rack. This is consistent with what is probably the minimum rack modification--moving the SLA attach points down by changing the lengths of the four sets of outside support tubes.

2.2 In-flight Transposition of the CSM Around the PM

This operation is required whenever the CSM performs the docking maneuver and accessibility to the PM film canisters from within the MDA is provided. The latter provision dictates that the existing forward drogue be mated with a probe on the MDA. This docked orientation is particularly convenient for LMSS operation with the Orbital Assembly. It also is advantageous for retrieving earth-orbital data. LMSS film does not have to be recovered until docking to the MDA is completed, and final drogue storage can be within the Workshop rather than within the PM. If the necessary electrical connections between the CSM and the PM could be made without removing the CSM probe and forward PM drogue, these components would never have to be removed and replaced from within a depressurized CM. What appears to be a very difficult operation for the crew would therefore be eliminated. (An argument against this point can be made: If the earth orbital mission is for checkout of the crew as well as the LMSS, the probe and drogue should at least be removed from within a depressurized CM as this operation is required in lunar orbit.)

The problem with in-flight transposition of the CSM is the lack of a stabilization system on the PM. Torques induced during CSM undocking from the forward end might induce tumbling of the PM such that redocking at the aft end would be impossible. A stabilized PM can be provided in two ways:

2.2.1 A cold gas attitude control system may be added to the PM. Several systems of this type have been developed and flown. A likely choice might be the system used on the Gemini Augmented Target Docking Adapter.

2.2.2 The PM may be stabilized by temporarily attaching it to the Orbital Assembly after rendezvous. This could be done with bayonet fittings or by an electromagnet. An EVA to secure a temporary attachment is not considered feasible because the CM tunnel is covered by the PM and the side hatch is not designed to be resealed. Depending on the time required for the undocking, transposition, and redocking, the Orbital Assembly can be under active or passive stabilization. Active stabilization is limited by the S-IVB Instrument Unit (IU) lifetime which is approximately 7-1/2 hours. Active stabilization after rendezvous is less than this, however, because of the time required for CSM phasing at low altitude and for the Hohmann transfer to the Workshop. Conceivably the IU control system could leave the S-IVB and Airlock Module in a gravity gradient stabilized orientation before expiring. Any perturbations to this passive stabilization due to PM impulses imparted to the Orbital Assembly would have to be removed by the CSM RCS system before subsequent undocking from the PM. It is expected that the inertia of the Assembly combined with careful operations will prevent intolerable tumbling from loads induced in undocking.

2.3 Final PM and CSM Docking

The same considerations on active vs. passive S-IVB stabilization discussed in Section 2.2.2 apply for final PM docking to the MDA, subsequent CSM undocking, and final CSM docking to another MDA port. If the S-IVB active stabilization system is in operation throughout this sequence, there is no problem. However, if the first docking impulse tumbles a passively stabilized Workshop, reacquisition of a gravity gradient stabilized attitude of the Workshop plus PM must be obtained by the CSM RCS before it undocks from the PM. If this proves not feasible, alternatives are to extend the IU lifetime, or add a separate S-IVB Workshop stabilization system. Final securing of the PM to the MDA must be done from within the MDA after it is activated.

3.0 DOCKING METHODS

The six methods of docking the PM to the MDA are described in detail in the order they are presented in Table I.

3.1 CSM, Docked to Permanent Inline Aft Collar, Docks Forward Collar to MDA

This method requires addition of a permanent aft docking collar to the PM by either of the ways discussed in Section 2.1. The final docked orientation is the optimum for LMSS operation from within the Workshop. Transposition of the CSM around the PM is required as discussed in Section 2.2. This method does not require retention of the PM launch support rack for the docking operations, nor does it require an EVA. Visibility from within the CM is hampered during final PM docking. This problem can be resolved by the addition of small mirrors on the PM.

3.2 CSM, Docked to Permanent Offset Aft Collar, Docks Forward Collar to MDA

This method also results in the optimum LMSS orientation for operation with the Assembly. It is proposed to eliminate the modifications described in Section 2.1. The permanent aft collar is mounted offset from the centerline of the PM, and this requires retention of the launch support rack. The collar is mounted on the base of the rack as close as possible to the PM battery compartment. It is tilted such that the plane of the collar is perpendicular to a line connecting the centers of the forward and aft drogues. Figure 1 illustrates this concept. The angle made by the aft collar and the base-plane of the rack, as scaled from Figure 1, is approximately 11°.

For perfect PM-MDA alignment, the CSM would nominally approach the MDA with its centerline offset 11° from the centerline of the MDA port. This is one degree outside the specified maximum angle. However, the same 10 degree tolerance should apply to the angle the PM makes with the centerline of the MDA port, and therefore any CSM to MDA angle (in the plane of the 11° fixed offset) between 1° and 10° meets the specification as applied to either the CSM or PM. Although the allowable docking alignment is decreased from a cone angle of 20° to 9°, it can be met with proper targets and care in the operation.

This method requires transposition of the CSM around the PM as described in Section 2.2, but no EVA. Visibility during docking is improved over the cases when the two PM docking collars are directly opposite each other.

3.3 CSM Docks Side of PM to MDA

This method does not require relocation of the battery compartment or CSM transposition. A side docking port is added to the PM opposite the IR baffle. During docking to the MDA, the CSM must translate sideways. Because the PM is docked to the front of it, side-translation RCS jets are offset from the combined center of mass. Thus a proper combination of translation plus counter-rotation jets must be fired. As RCS thrust is fixed, precise sequencing of the firings is required. CSM guidance computer reprogramming is therefore required, and this might have to wait until accurate inertial properties are known. Alignment of the PM side docking port with CSM translational and rotational planes must be kept to a much tighter tolerance than now specified, and the required angle might be unacceptable for LMSS operation with the CSM. These considerations raise questions concerning the feasibility of side-docking the PM to the MDA with an active CSM.

The final docked position leaves the LMSS film canisters exposed to the space environment. EVA is required before the LMSS can be used with the Assembly, and for film retrieval. Visibility during docking is improved in the sense that both the PM and MDA docking collars can be seen by the crew from within the CSM. However, depth perception becomes a problem in achieving proper pre-alignment along the CSM-PM roll axis.

3.4 CSM Docks Permanent Aft Collar to MDA

This method does not require the CSM transposition maneuver. Therefore, it results in the PM film compartment being exposed to the space environment. If the aft collar is directly opposite the forward collar, the battery compartment must be relocated by either of the methods outlined in Section 2.1. It could be offset as in method 3.2. Although the LMSS is in a non-optimum position, other experiments (EO-O) could be mounted around the aft collar so they are accessible for the MDA. In fact, the aft collar could be incorporated in a pressurized compartment to provide "shirt-sleeve" accessibility.

3.5 CSM Docked to EVA Installed Aft Collar, Docks Forward Collar to MDA

This method depends on EVA to install the aft collar, thus eliminating permanent additional docking provisions. It is proposed only to minimize changes in the present PM design. Operationally, it is very complex. The sequence would occur after the CSM with the PM docked to it transfers to and rendezvous with the Orbital Workshop. The PM is temporarily attached to the unmanned Assembly. The CSM then undocks from the PM, and docks to the MDA. The crew activates the Airlock Module and then one astronaut performs an EVA with egress through the Airlock to install the extra drogue assembly to the aft end of the PM.

The concept of the extra drogue and docking collar is shown in Figure 2. Three struts are mounted to the collar. The other end of each strut is equipped with a clevis. Each clevis is attached to a tab on the exterior of the MDA by a quick-release pin. The extra drogue assembly is installed here prior to the launch of the AAP-2. Three similar tabs are mounted around the circumference of the PM aft of the separation joint, but are tied to the PM prime structure at this joint. The astronaut removes the three pins from the tabs on the multiple docking adapter, transports the docking collar to the aft of the PM, mates each clevis with the PM tabs and installs the same three pins.

The EVA astronaut then joins the rest of the crew in the CM and the CSM transfers and docks to the new aft drogue. The temporary attachment of the PM to the Workshop is served and the active CSM docks the forward drogue of the PM to a probe on the MDA. The attachment is secured from within the MDA after the CSM redocks to it.

Stabilization for docking to the PM is provided by the temporary attachment, and since this attachment must be made for the docking collar installation, addition of a PM stabilization system need not be considered. If active stabilization of the Workshop is mandatory during these docking and undocking operations, then this method is not feasible without changes in the Assembly as discussed in Section 2.3.

3.6 PM, Snared to Orbital Assembly by CSM, Is Pulled Into Docking Port From MDA

This method is the only one that does not require the addition of a second docking collar. It does, however, require additions to the MDA. After Workshop injection two booms are automatically extended from the MDA. The booms are parallel to the centerline of the MDA docking port that is reserved for the PM, and are equally spaced on opposite sides of this centerline. Their separation is slightly greater than the diameter of the PM. The outboard end of the booms is equipped with a snaring mechanism, such as a cradle covered with velcro or bayonet fittings. The PM is equipped with the other half of the snaring mechanism.

After rendezvous, the CSM maneuvers the PM into the snaring mechanism, and undocks. The crew then docks the CSM to the MDA and activates it. By some means, either a controlled rotating mechanism on the end of a boom, or an EVA through the Airlock, the PM is pitched relative to the extended booms so that its center-line is parallel to the booms, and the forward PM port is orientated toward the MDA. Latching mechanisms forward on the PM can then be engaged with the booms inboard of the snaring mechanism. The proper orientation is thus held, and the booms are simultaneously retracted until the probe tip in the MDA port engages the forward drogue of the PM. Docking is secured from within the MDA.

PM modifications can be kept minimal with this method. The booms must have sufficient integrity so that the active CSM snaring maneuver does not cause their structural failure. The maneuver possibly will prove not feasible due to the delicate operations required. There is no necessity to break the snared attachment after it is once made because the booms may be left partially extended and attached to the PM.

4.0 RETENTION OF THE LAUNCH SUPPORT RACK

Only one method for hard docking the PM to the MDA requires retention of the launch support rack with the PM. Retention of the rack could prove convenient for mounting relocated or additional equipment. If additional experiments such as those of the EO-0 package are to be included, PM structural modifications can be reduced by retaining the rack and adding an upper rack to support the prime docking collar.

Retention of the rack has some disadvantages. The increase in moments of inertia negate control analysis performed for the PM alone, and the additional mass and flexibility of the rack could aggravate the attitude control problem. With a symmetrical upper rack, a survey camera viewing obstruction exists. PM thermal control analyses are complicated by retention of the rack. The tubular space-frame construction of the rack is not readily adaptable to mounting additional experiments; secondary structure weight for this purpose could be substantial. The cost of retention of the rack has been estimated at 1 to 1.5 million dollars, and a four month schedule slip is associated with it. With five of the six docking methods described, the only justification for keeping the rack with the PM is for carrying heavy additional experiments. In the case of EO-0, availability of the instruments in time for AAP-1 is in question. AS-207 payload margin when carrying the rack and EO-0 is estimated at 100 pounds. If CSM RCS capability is increased to provide backup deorbit, a deficit of approximately 1600 pounds results.

5.0 SUMMARY

It has not been the purpose of this memorandum to recommend an approach for docking the PM to the Orbital Assembly but to bring forth advantages and disadvantages of six possible methods. Complexity in operations can be diminished only at the expense of increasing changes to the PM. Retention of the rack can be justified only after a definite decision to provide funds necessary for development of EO-0 along its present concept or by a choice of the offset docking method. A lesser version of EO-0 could be mounted directly to the PM thus alleviating many of the problems associated with keeping the rack.

6.0 ACKNOWLEDGMENT

Some of the concepts contained in this memorandum are the ideas of MSC, MSFC, and other Bellcomm personnel. The author particularly appreciates contributing discussions with Messrs. B. G. Jackson, R. O. Piland, and R. F. Thompson of MSC, R. D. Stewart of MSFC, M. W. Krueger of NASA-MLA, and G. M. Anderson and K. E. Martersteck of Bellcomm.

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Attachments
Table I
Figures 1 and 2

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TABLE 1

<table>
<tr><td>METHOD DESCRIPTION AND COMMENTS / PM MODIFICATIONS AND OPERATIONS</td><td colspan="2">CSM, DOCKED TO PERMANENT INLINE AFT COLLAR, DOCKS FORWARD COLLAR TO MDA</td><td colspan="2">CSM, DOCKED TO PERMANENT OFFSET AFT COLLAR, DOCKS FORWARD COLLAR TO MDA</td><td>CSM DOCKS SIDE OF PM TO MDA. (FEASIBILITY QUESTIONED, NO ACCESS TO INSIDE OF PM FROM MDA)</td><td colspan="3">CSM DOCKS PERMANENT AFT COLLAR TO MDA (WRONG END FOR M & SS REUSE)</td><td>CSM, DOCKED TO EVA INSTALLED AFT COLLAR, DOCKS FORWARD COLLAR TO MDA (EXTENSIVE OPERATIONS)</td><td>PM, SNARED TO ORBITAL ASSEMBLY BY CSM, IS PULLED INTO DOCKING PORT FROM MDA (REQUIRES MDA ADDITIONS)</td></tr>
<tr><td>ADD'L DOCKING PROVISION PERMANENTLY ADDED</td><td colspan="2">YES, AFT END</td><td colspan="2">YES, AFT END OFFSET</td><td>YES, SIDE OF PM OPPOSITE IR BAFFLE</td><td colspan="3">YES, AFT END
INCLINE (first two columns) / OFFSET (third column)</td><td>ONLY PM FITTINGS</td><td>ONLY SNARING MECHANISM</td></tr>
<tr><td>PM BATTERY COMPARTMENT RELOCATED</td><td>YES</td><td>NO</td><td colspan="2">NO</td><td>NO</td><td>YES</td><td>NO</td><td>NO</td><td>NO</td><td>NO</td></tr>
<tr><td>FORWARD END OF PM INSIDE SPS NOZZLE DURING LAUNCH</td><td>NO</td><td>YES</td><td colspan="2">NO</td><td>NO</td><td>NO</td><td>YES</td><td>NO</td><td>NO</td><td>NO</td></tr>
<tr><td>RACK RETAINED WITH PM</td><td colspan="2">NOT NECESSARY FOR DOCKING</td><td colspan="2">YES</td><td>NOT NECESSARY FOR DOCKING</td><td colspan="2">NOT NECESSARY FOR DOCKING</td><td>YES</td><td>NOT NECESSARY FOR DOCKING</td><td>NOT NECESSARY FOR DOCKING</td></tr>
<tr><td>TRANSPOSITION AROUND PM WITH CSM</td><td colspan="2">YES</td><td colspan="2">YES</td><td>NO</td><td colspan="3">NO</td><td>YES</td><td>NO</td></tr>
<tr><td>PM TEMPORARILY ATTACHED TO ORBITAL ASSEMBLY</td><td>YES</td><td>NO</td><td>YES</td><td>NO</td><td>NO</td><td colspan="3">NO</td><td>YES</td><td>YES, SNARED</td></tr>
<tr><td>PM STABILIZATION SYSTEM ADDED</td><td>NO</td><td>YES</td><td>NO</td><td>YES</td><td>NO</td><td colspan="3">NO</td><td>NO</td><td>NO</td></tr>
<tr><td>EVA REQUIRED TO DOCK PM TO MDA</td><td colspan="2">NO</td><td colspan="2">NO</td><td>NO</td><td colspan="3">NO</td><td>YES</td><td>PROBABLY</td></tr>
</table>

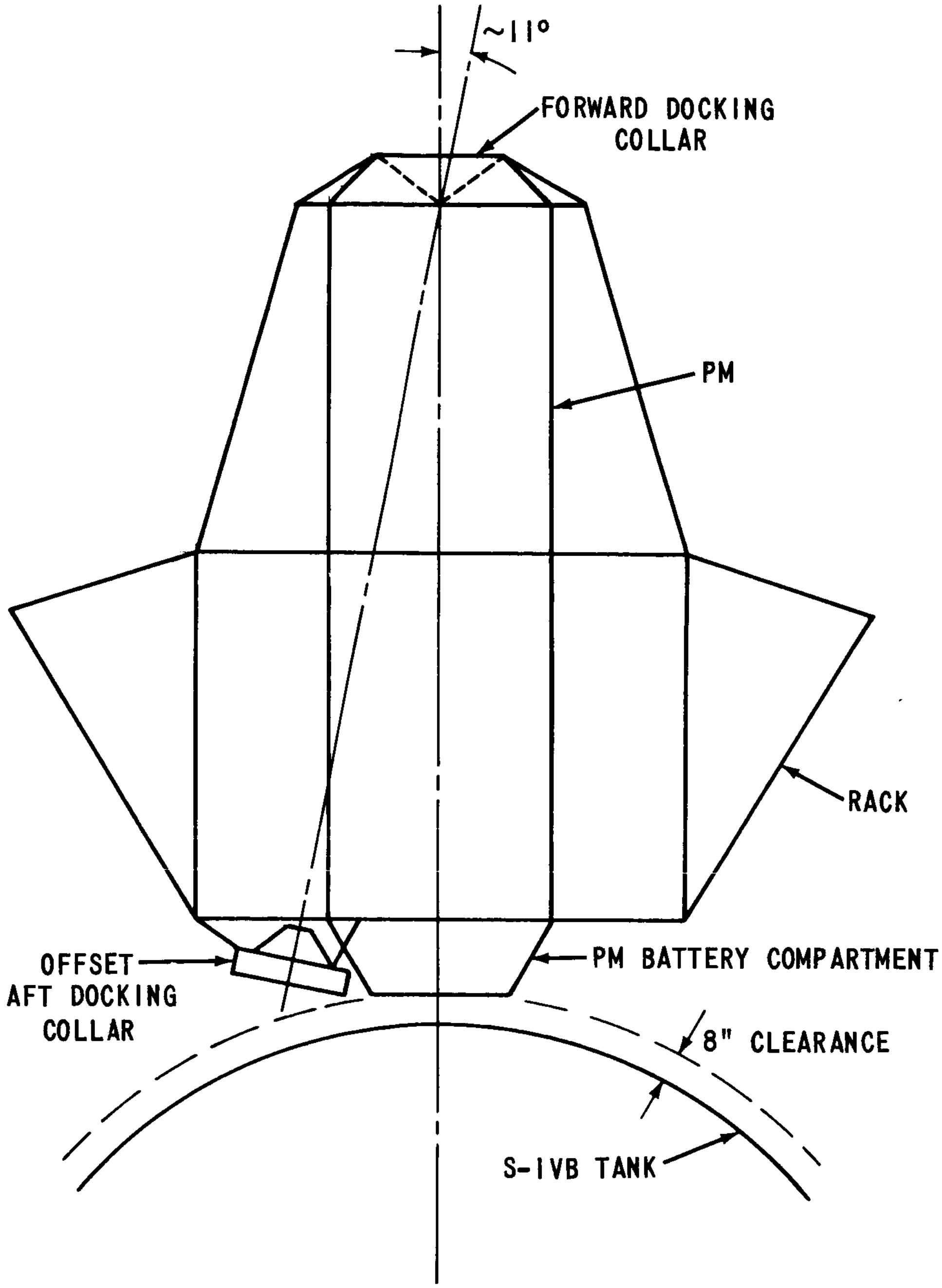

FIGURE 1 - INSTALLATION OF OFFSET AFT DOCKING COLLAR

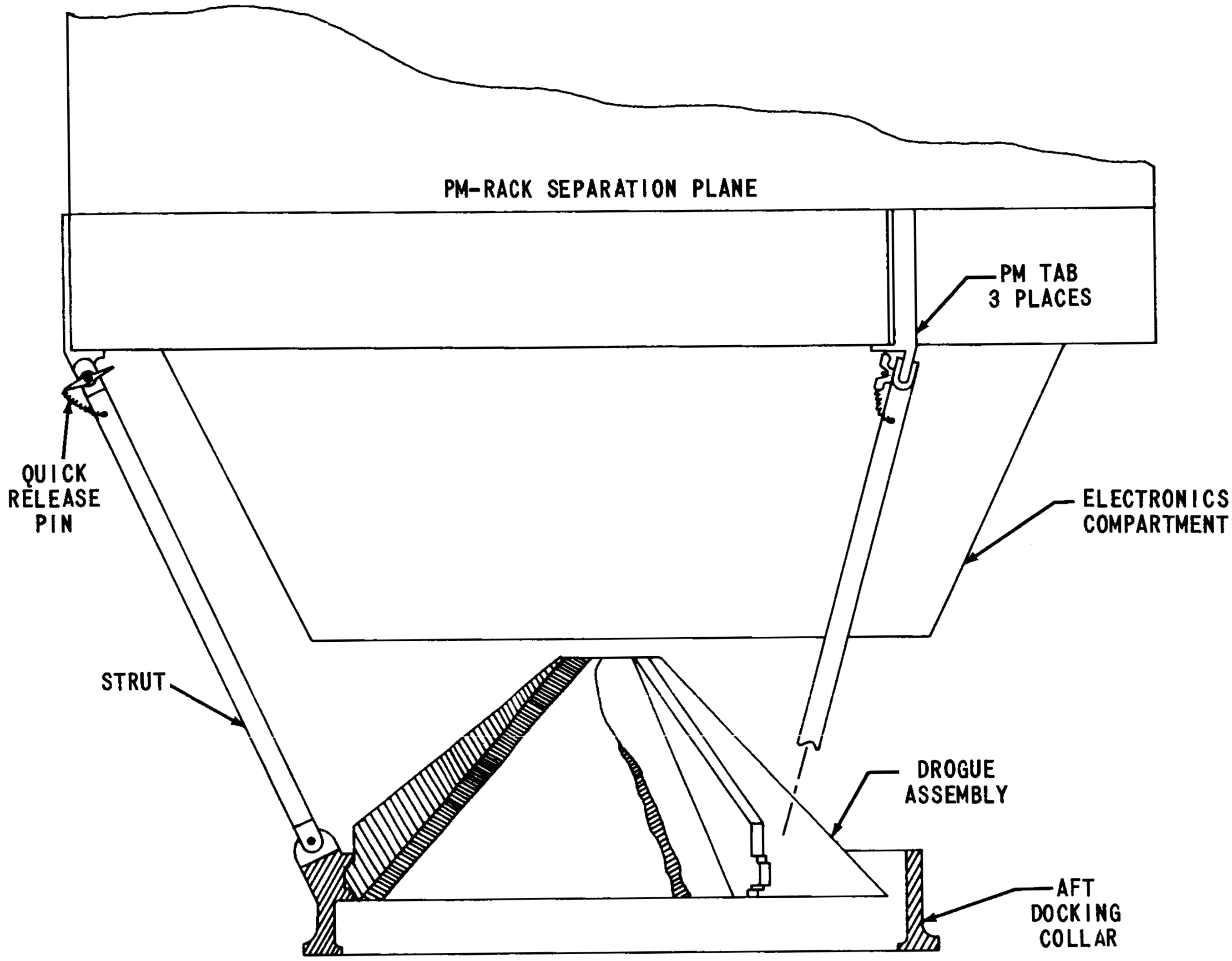

FIGURE 2 - EVA INSTALLED AFT DOCKING COLAR